(12) UK Patent Application (19) GB (11) 2 212 010 (13) A

(43) Date of A publication 12.07.1989

(21) Application No 8818809.9

(22) Date of filing 08.08.1988

(30) Priority data
(31) 84367 (32) 04.11.1987 (33) IL

(71) Applicant
Amcor Ltd

(Incorporated in Israel)

98 Ygal Alon Street, Tel Aviv, Israel

(72) Inventors
Jonathan Lison
Emanuel Mendes

(74) Agent and/or Address for Service
J Miller & Co
Lincoln House, 296-302 High Holborn, London, WC1V 7JH, United Kingdom

(51) INT CL⁴
A61N 5/06, H05B 33/00

(52) UK CL (Edition J)
H2H HLL3 H25G
A5R REH
U1S S1032

(56) Documents cited
GB 1604888 A GB 1543722 A EP 0214712 A1
EP 0047418 A1 WO 84/04463 A1 US 4675575 A
US 4329625 A US 4029991 A US 3740570 A

(58) Field of search
UK CL (Edition J) A5R REH, H2H HLL3
INT CL⁴ A61N, H05B

(54) **Radiation therapy apparatus using LED matrix**

(57) A matrix of LEDs 20 provides a non-coherent light source as a substitute for more commonly employed laser devices and can be controlled to combine the operating characteristics of continuous beam helium neon lasers with the low cost convenience and high powered pulsed output of laser diodes. The radiation wavelength may be in the red or infra-red range. A switch (8), (Fig 1), allows selection of continuous and pulsed modes. In the continuous mode, a circuit 12 provides a continuous d.c. voltage on a rail 28 and a HEXFET 33 functions as a short circuit, the radiation intensity being varied by varying the amplitude of the d.c. voltage. In the pulsed mode, a fixed voltage is applied to rail 28, HEXFET 33 is pulsed on and off by a circuit 16, and the radiation intensity is varied by varying the pulse frequency and/or duty cycle. A timer (10), (Fig 1), turns off the power supply to terminate the therapy after a predetermined time.

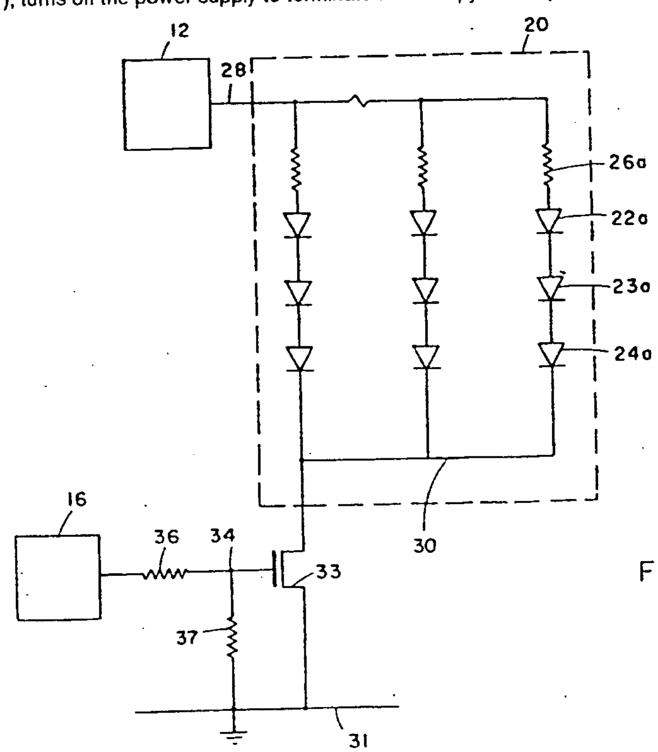

Fig.2

GB 2 212 010 A

2212010

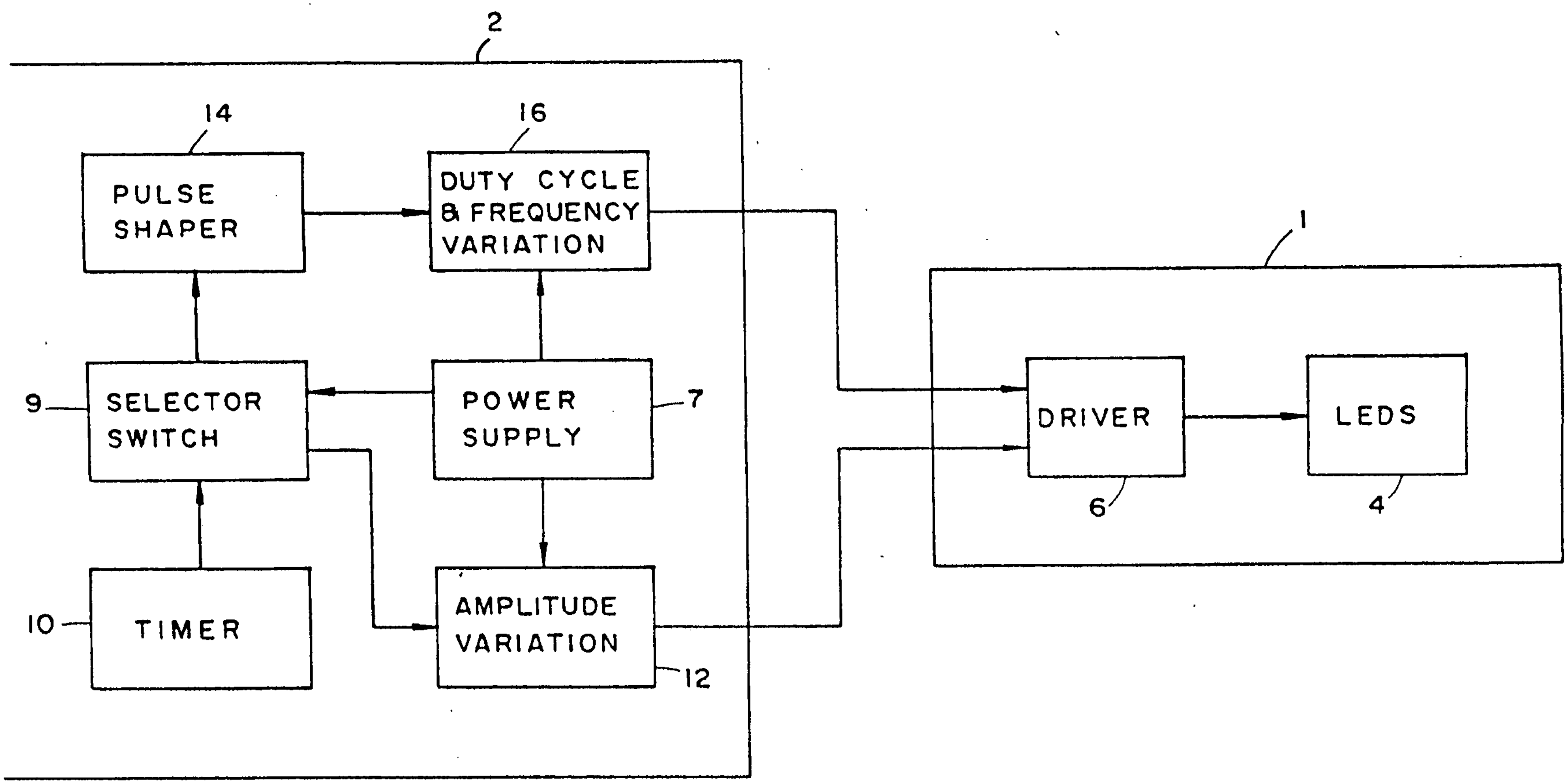

Fig. 1

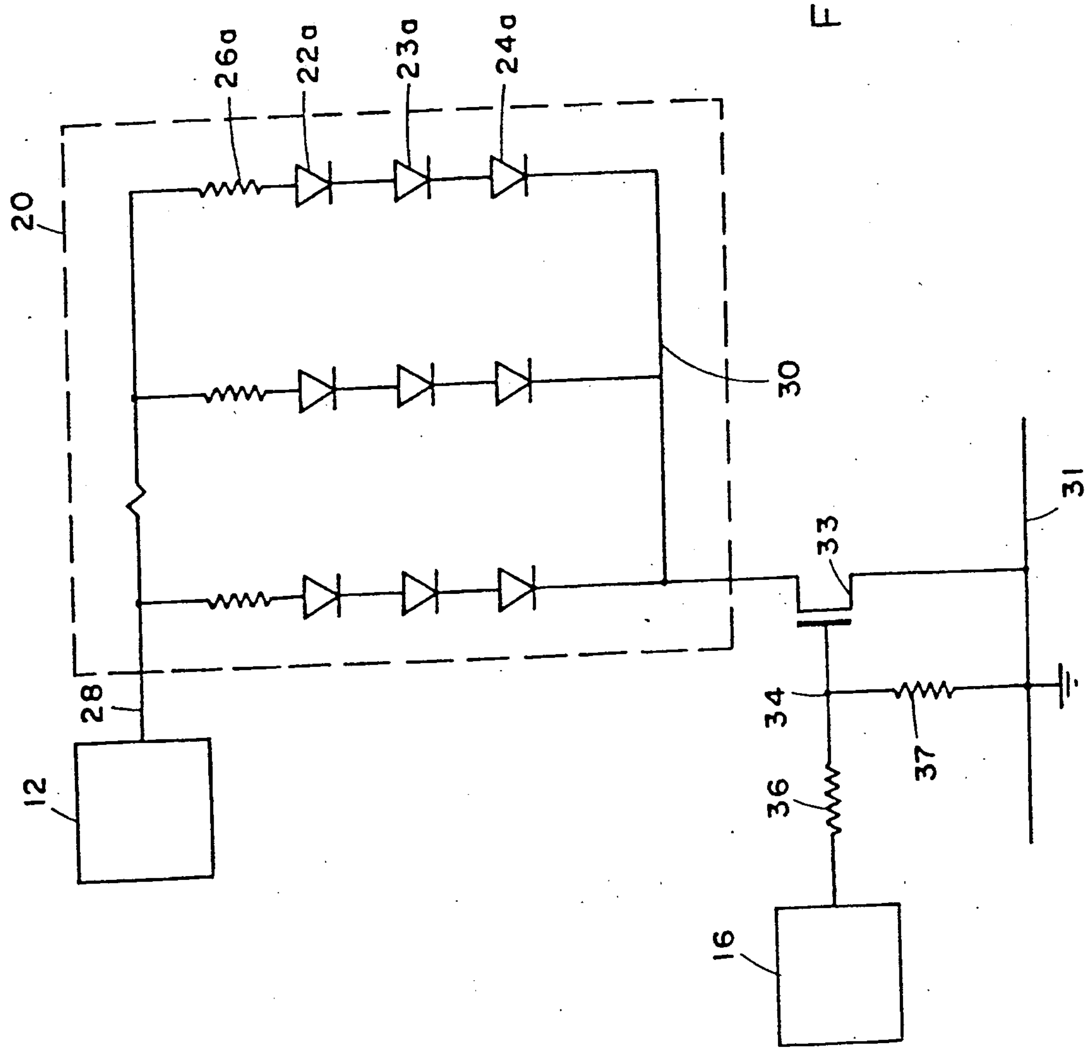

Fig. 2

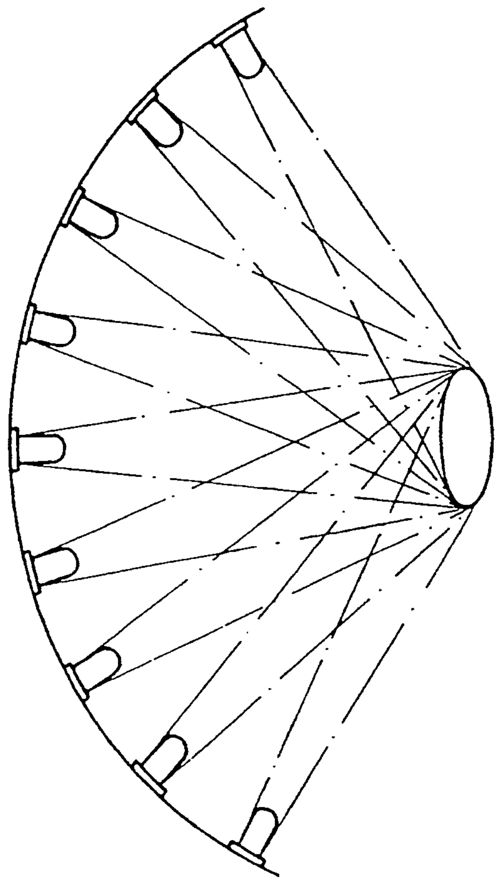

Fig.3

2212010

An Apparatus for Use in Radiation Therapy

BACKGROUND OF THE INVENTION

This invention relates to an apparatus for use in radiation therapy, and in particular to an apparatus which may effectively be used as a substitute for certain laser radiation devices.

Laser therapy using helium neon lasers, in particular, has existed for many years and, more recently, has been integrated with infrared lasers which has extended the limits of the technique. Among the wide range of laser therapy applications, low power helium neon and minimum power infrared lasers are used in order to effect treatment either to the surface of the body so as to heal wounds, burns and so on, or, alternatively, for the treatment of inflammatory rheumatoid diseases, diseases of the locomotor system, and so on, depending on the depth of penetration of the laser being employed.

Such lasers are not surgical lasers, and are therefore not used in order to cut body tissue. Moreover, they produce no heating effect on the body tissue, and the exact mechanism by which they achieve their therapeutic results is not precisely known. It has been suggested that the specific wavelength associated with laser light, and a characteristic of the lasing medium being employed, determines the depth to which it will penetrate

body tissue, and be absorbed, reflected and scattered thereby. It has also been suggested that the energy of the laser beam excites molecules within the cells of damaged tissue, and thereby accelerates their repair.

Conventional laser therapy is expensive. Helium neon lasers, which utilise a conventional lasing medium, are large and highly expensive. They provide a continuous, relatively low power (approximately 10 mW) beam of coherent radiation having a sharply defined wavelength which remains stable to within ± 1 nm.

Infrared lasers, on the other hand, are based on semiconductor diode technology, and are very much less expensive than their helium neon counterparts. The output from a laser diode is a sharply diverted cone which is difficult to couple efficiently to an optical system. The output is also highly coherent, resulting from the physics of the laser action, thus dictating the need for diffraction limited collection, focusing and coupling optics. These add significantly to the cost of the resulting system. Laser diodes are, essentially, light emitting diodes (LEDs), wherein the stimulated emission occurs at the same wavelength a corresponding LED would be most likely to emit. However, a higher operating current is required in a laser diode in order to maintain an adequate population inversion by producing a high density of electron-hole pairs. Consequently, the output of a laser diode is essentially monochromatic whilst a comparable LED emits radiation within a somewhat broader spectral bandwidth.

The population inversion in laser diodes is achieved by passing a relatively high current through the diode. However, on account of the relatively high current density through the laser diode, such lasers may only be used in a pulsed mode, wherein a current sufficient to cause population inversion is passed through the diode as a pulse train consisting of pulses of very short duration (in the order of nanoseconds). Consequently, the switching frequency of the laser diode needs to be very fast and a power supply must be provided which can generate such

pulses. The electronics required in such a power supply is complex and correspondingly expensive.

In spite of this drawback, laser diodes have many advantages over conventional helium neon lasers for use in medical therapy. They are not only substantially less expensive than conventional helium neon lasers, but are also available with a range of different frequency characteristics, currently in the infrared range. Moreover, on account of their very small size they can be easily manually manipulated, whereas conventional helium neon lasers of equivalent power rating are unmanageably large and require cooling when providing high power output (e.g. 10 W).

It would be desirable to combine the continuous operating characteristics of helium neon lasers with the low cost convenience and high powered pulsed output of laser diodes. It has already been explained that the properties of laser light which are thought to be responsible for its therapeutic effect, are its monochromacity and its coherence. Therefore, it has never been suggested to utilise the radiation emitted by standard LEDs for laser therapy, precisely because such LEDs do not exhibit these properties. However, recent research seems to suggest that such LEDs may indeed be used in irradiation equipment to provide effective therapeutic treatment of a wide range of ailments.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an apparatus for use in radiation therapy, comprising:

a light-emitting diode array arranged to irradiate a discrete area,

a variable power supply source selectively adapted to provide either a continuous or pulsed voltage across said diodes,

a control circuit for varying the magnitude of said continuous voltage and the frequency and duty cycle of said pulsed voltage, and

a timer circuit for switching off said power supply source after a predetermined time interval.

The light emitting diodes used in the present invention are standard, low cost components which are provided with none of the complex optics associated with laser diodes. The diodes of the present invention may be used in either a continuous or pulsed mode, and the control circuit is provided with a selector switch in order to select which mode is to be employed.

The wavelength of the radiation is a function of the particular type of LED selected and may be in the red or infra-red range of the spectrum. Thus, the quality of radiation may easily be predetermined to correspond to that of conventional helium neon or infra-red lasers without changing the configuration of the radiation source itself.

Preferably, the diodes are connected in a matrix comprising several parallel banks each of which includes a number of series-connected diodes. The current flowing through each individual bank of diodes is limited by means of a resistor, and the total current flowing through all the parallel banks of diodes is limited by means of a HEXFET. By employing a large number of diodes, a relatively high power radiation source may be constructed with a reasonably sharply defined, predetermined wavelength and a bandwidth of ± 25 nm.

When using the system in the continuous mode, the voltage applied across the diode matrix is varied in order to adjust the current flowing through the diodes, and thereby the net power output. When the system is used in the pulsed mode, a pulse chain is applied to the gate of the HEXFET and the total current flowing through the diode matrix and also through the HEXFET may then be varied by changing the frequency and/or the duty cycle of the pulses.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with regard to an apparatus for use in radiation therapy, employing low cost LEDs, with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram showing functionally the apparatus according to the invention;

Fig. 2 shows a preferred arrangement for connecting the LEDs shown functionally in Fig. 1; and

Fig. 3 shows an arrangement for connecting the LEDs shown in Fig. 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring to Fig. 1, there is shown a compact radiation source 1 and an associated control unit 2. The radiation source 1 comprises a plurality of LEDs 4 which receive power via a driver circuit 6. The control unit 2 contains a power supply 7 coupled to a selector switch 9 whose function is to determine the mode of operation (pulsed or continuous) of the control unit 2. The selector switch 9 is energised via a timer 10 which can be constituted by a standard clock circuit provided with "set time" switches, and whose function is to disable the control circuit 2 after a preset time has elapsed.

One output from the selector switch 9 is fed to an amplitude variation circuit 12 whose output is a variable amplitude d.c. signal which is fed to the driver 6 of the radiation source 1. A second output from the selector switch 9 is fed to a pulse shaper circuit 14 whose output is a square wave pulse of a predetermined amplitude. The output from the pulse shaper circuit 14 is fed to a duty cycle and frequency variation circuit 16 whose output is fed to the driver 6 of the radiation source 1.

Thus, depending on the position of the selector switch 9, a variable amplitude d.c. signal or, alternatively, a constant amplitude square wave pulse of variable frequency and duty cycle is fed to the driver circuit 6 of the radiation source 1.

Fig. 2 shows the radiation source 1 in greater detail. The LEDs 4 are arranged in the form of a LED matrix 20 comprising a plurality of parallel branches each of which contains a predetermined number of LEDs connected in series. Thus, in Fig. 2 three LEDs 22a, 23a and 24a are connected in series and constitute one parallel branch of the diode matrix 20. The current flowing through this branch is limited by means of a series resistor 26a, and the resulting branch is connected between a high voltage d.c. rail 28 and a low voltage d.c. rail 30. Thus, one terminal of the series connected current-limiting resistor is connected to the high voltage rail 28 whilst the cathode of LED 24a is connected to the low voltage rail 30. The connection of all other branches of the LED matrix 20 is identical.

Connected between the low voltage rail 30 of the LED matrix 20 and the ground rail 31 is a HEXFET 33 which constitutes the driver circuit 6 shown in Fig. 1. The HEXFET 33 is provided with drain and source terminals connected to supply rails 30 and 31, respectively, and a gate terminal 34 which is coupled, via a series resistor 36, either to the duty cycle and frequency variation circuit 16 or, alternatively, to the amplitude variation circuit 12, depending on the position of the selector switch 9 shown in Fig. 1. Also connected between the gate terminal 34 of the HEXFET 33 and the ground rail 31 is a high value shunt resistor 37. The HEXFET is a field effect transistor which is specially adapted to pass a high current from its drain to source terminals when a voltage is applied at its gate terminal.

When the selector switch 9 (Fig. 1) is set to "continuous" mode, a variable amplitude d.c. signal is applied to the high voltage rail 28, and a sufficiently high d.c. voltage is applied to the gate 34 of the HEXFET 33 such that the HEXFET 33 acts, effectively, as a closed switch. Under these circumstances, the total current flowing through the LED matrix 20 flows through the HEXFET 33 to ground, and this current is

limited only by the setting of the amplitude variation circuit 12.

On the other hand, when the selector switch 9 is set to the "pulsed" mode, the signal applied to the gate 34 of the HEXFET 33, via the series resistor 36, is a square wave pulse of variable duty cycle and frequency. The amplitude of this pulse is constant and is such that the HEXFET 33 passes current in response to a non-zero signal on its gate 34. In effect, the HEXFET 33 operates as a switch wherein the current flowing between its drain and source terminals is a function of the d.c. voltage pulse applied to its gate terminal. Thus, in this configuration, the HEXFET 33 acts as a buffer which permits a high amplitude current pulse to pass through the LED matrix 20 in response to a pulse applied to its gate 34.

Fig. 3 shows a preferred arrangement for the physical connections of the LEDs shown schematically in Fig. 2. The LEDs are arranged such that their light output is focussed over a sharply defined area. In a preferred embodiment, the area over which the LEDs are focussed is substantially circular with a diameter of 1.2 cm, and this has been found to have beneficial therapeutic results. It will be understood that the greater the number of LEDs connected within the LED matrix 20 of Fig. 2, the greater will be the intensity of the light output by the radiation source 1 (Fig. 1).

The operation of the system is as follows. When the selector switch 9 is set to the "continuous" mode, the amplitude variation circuit 12 operates so as to provide a variable amplitude d.c. voltage between the high voltage supply rail 28 and the ground terminal 31 via the HEXFET 33 which, as explained above, functions as a short circuit. Thus, by varying the setting of the amplitude variation circuit 12, the overall current flowing through the LED matrix 20 may be varied and, therefore, the light intensity of the radiation source 1.

When the selector switch 9 is set to the "pulsed" mode, a predetermined voltage is applied to the high voltage rail 28, and a square wave pulse of predetermined amplitude is applied to the gate 34 of the HEXFET 33 via the series resistor 36. Current will only flow through the HEXFET 33 when its gate voltage is greater than a predetermined value (i.e. the pinch-off voltage), or when the pulsed voltage applied to the gate is non-zero. Under these circumstances, the current flowing through the HEXFET 33, and thus through the LED matrix 20, is a function of the potential difference between the high voltage rail 28 and the ground rail 31. The average current flowing through the HEXFET 33 may thus be varied by varying either the frequency or, alternatively, the duty cycle of the pulse appearing at its gate 34.

The operator of the system is therefore able to choose two modes of operation by means of the selector switch 9. In the "continuous" mode, the radiation source 1 emits radiation continuously with a magnitude determined by the amplitude variation circuit 12. In the "pulsed" mode, the radiation source 1 emits pulses of radiation whose average intensity may be varied either by varying the duty cycle or, alternatively, the frequency of the pulses produced by the pulse shaper circuit 14.

Although in the preferred embodiment the HEXFET is used as an on-off switch, it is also possible to employ the HEXFET as a current limiter wherein the current flowing from its drain to source terminals is a function of the voltage applied to its gate.

Thus, the invention affords a low cost radiation therapy apparatus producing a non-coherent source of radiation focussed over a small area. The exact wavelength of the radiation is confined within a relatively narrow bandwidth (± 25 nm) and its central value may be predetermined by suitable selection of the LEDs in the LED matrix 20. In both the "continuous" and "pulsed" modes of operation, the average intensity of the emitted radiation may easily be varied by the

operator, and the therapy time may be preset by means of the integral timer circuit provided. Although the radiation emitted by the radiation source of the invention is neither coherent nor monochromatic, successful therapeutic results have nevertheless been observed.

CLAIMS:

1. An apparatus for use in radiation therapy, comprising:

a light-emitting diode matrix arranged to irradiate a discrete area,

a variable power supply source selectively adapted to provide either a continuous or pulsed voltage across said diodes,

a control circuit for varying the magnitude of said continuous voltage and the frequency and duty cycle of said pulsed voltage, and

a timer circuit for switching off said power supply source after a predetermined time interval.

2. An apparatus according to Claim 1 wherein said light-cutting diodes are arranged in the form of an LED matrix comprising a first predetermined number of parallel branches each containing a second predetermined number of series connected LEDs.

3. An apparatus according to Claim 1 or 2 wherein the current flowing through each said branch is limited by a resistor.

4. An apparatus according to any one of the preceding claims wherein the current flowing through said plurality of LEDs is limited by means of a HEXFET connected in series between said power supply and said plurality of LEDs.

5. An apparatus according to Claim 4 wherein said continuous voltage is applied to the gate of said HEXFET thereby allowing said current to flow continuously through said plurality of LEDs.

6. An apparatus according to Claim 5 wherein the radiation intensity of said LEDs is varied by varying the amplitude of said continuous voltage.

7. An apparatus according to Claim 4 wherein said pulsed voltage is applied to the gate of said HEXFET thereby allowing said current to flow through said plurality of LEDs in synchronism with said pulsed voltage.

8. An apparatus according to Claim 7 wherein the radiation intensity of said LEDs is varied by varying the frequency and/or the duty cycle of said pulsed voltage.

9. An apparatus according to any one of the preceding claims wherein said LEDs are adapted to emit radiation having a predetermined frequency bandwidth.

10. An apparatus according to any one of the preceding claims wherein said LED matrix includes a plurality of LEDs each of which emits a cone of light, said cones of light being adapted to intersect over said discrete area.

11. An apparatus for use in radiation therapy substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

12. Any novel integer or step, or combination of integers or steps, hereinbefore described and/or shown in the accompanying drawings, irrespective of whether the present claim is within the scope of, or relates to the same or a different invention from that of, the preceding claims.

Published 1989 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP